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# EDITORS' PREFACE

*Threshold Concepts and Transformational Learning*

## *Introduction*

At the lower end of the ancient Canongate in Edinburgh there is a worn sandstone lintel over a small seventeenth-century doorway. It bears a Latin engraving on which is inscribed: 'Pax intrantibus, salus exeuntibus'. Peace to those who are entering, and safety to those about to depart. It is a modest reminder that a threshold has always demarcated that which belongs within, the place of familiarity and relative security, from what lies beyond that, the unfamiliar, the unknown, the potentially dangerous. It reminds us too that all journeys begin with leaving that familiar space and crossing over into the riskier space beyond the threshold. So, too, with any significant transformation in learning. As Leslie Schwartzman observes later in this volume, 'Real learning requires stepping into the unknown, which initiates a rupture in knowing'. By definition, she contends, all threshold concepts scholarship 'is concerned (directly or indirectly) with encountering the unknown'.

For readers new to the idea of threshold concepts the approach builds on the notion that there are certain concepts, or certain learning experiences, which resemble passing through a portal, from which a new perspective opens up, allowing things formerly not perceived to come into view. This permits a new and previously inaccessible way of thinking about something. It represents a transformed way of understanding, or interpreting, or viewing something, without which the learner cannot progress, and results in a reformulation of the learners' frame of meaning. The thresholds approach also emphasises the importance of disciplinary contexts. As a consequence of comprehending a threshold concept there may thus be a transformed internal view of subject matter, subject landscape, or even world view. Typical examples might be 'Marginal Cost', 'Opportunity Cost' or 'Elasticity' in Economics; 'Evolution' in Biology; 'Gravity' or 'Reactive Power' in Physics; 'Depreciation' in Accounting; 'Precedent' in Law; 'Geologic Time' in Geology; 'Uncertainty' in Environmental Science; 'Deconstruction' in Literature; 'Limit' theory in Mathematics or 'Programming' in Computer Science.

In attempting to characterise such conceptual gateways we have suggested in earlier work that they are *transformative* (occasioning a significant shift in the perception of a subject), *integrative* (exposing the previously hidden inter-relatedness of something) and likely to be, in varying degrees, *irreversible* (unlikely to be forgotten, or unlearned only through considerable effort), and

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frequently *troublesome*, for a variety of reasons. These learning thresholds are often the points at which students experience difficulty. The transformation may be sudden or it may be protracted over a considerable period of time, with the transition to understanding often involving 'troublesome knowledge'. Depending on discipline and context, knowledge might be troublesome because it is ritualised, inert, conceptually difficult, alien or tacit, because it requires adopting an unfamiliar discourse, or perhaps because the learner remains 'defended' and does not wish to change or let go of their customary way of seeing things.

Difficulty in understanding threshold concepts may leave the learner in a state of 'liminality', a suspended state of partial understanding, or 'stuck place', in which understanding approximates to a kind of 'mimicry' or lack of authenticity. Insights gained by learners as they cross thresholds can be exhilarating but might also be unsettling, requiring an uncomfortable shift in identity, or, paradoxically, a sense of loss. A further complication might be the operation of an 'underlying game' which requires the learner to comprehend the often tacit games of enquiry or ways of thinking and practising inherent within specific disciplinary knowledge practices. In this sense we might wish to talk of 'threshold practices' or 'threshold experiences' that are necessary in the learner's development.

This is our third book on the topic of threshold concepts. The first, *Overcoming Barriers to Student Understanding: Threshold Concepts and Troublesome Knowledge* (Meyer and Land, 2006), drew together the early seminal writings and some first disciplinary applications of this approach. It offered, in an exploratory fashion, a tentative conceptual framework and a lens through which to view the pedagogy of higher education anew. After a lively international symposium on this topic in Glasgow, Scotland in the autumn of 2006, a second volume was published. *Threshold Concepts within the Disciplines* (Land, Meyer and Smith, 2008) built and expanded on the first in significant ways. It provided more empirical data concerning the experience of threshold concepts and troublesome knowledge, particularly from the students' perspective. It also extended the range of disciplinary contexts in which thresholds had been studied. This encouraged further work to be undertaken, culminating in a second successful international conference in Kingston Ontario organised by Caroline Baillie in the summer of 2008, from which this third volume has taken shape.

With *Threshold Concepts and Transformational Learning* the empirical evidence for threshold concepts has been substantially increased, drawn from what is now a large number of disciplinary contexts and from the higher education sectors of many countries. The central section of this new volume adds to that evidence base, ranging across subjects that include, amongst others, economics, electrical engineering, education, clinical education, sociology, social justice, modern languages, law, computer science, philosophy, transport and product design, nanoscience, mathematics, biology, history and accounting. The authors included here work in colleges and universities in the United Kingdom, the USA, Canada, Sweden, Estonia, Australia, Hong Kong and the South Pacific. The opening section of the volume, moreover, challenges and extends the theoretical boundaries of the thresholds framework in relation to our understanding of

transition, liminality and the developmental process of learning, of conceptual structure, of how students experience difficulty, as well as new dimensions of troublesome knowledge and how we might both render conceptual understanding visible and assess it in a more dynamic fashion. The concluding section contains a substantial body of writing which furthers our understanding of the ontological transformations that are necessarily occasioned by significant learning, the learning thresholds, as we might term them, which might not be strictly conceptual, but are more concerned with shifts in identity and subjectivity, with procedural knowledge, or the ways of thinking and practising customary to a given disciplinary or professional community. We see here too, intriguing migratory instances of the application of threshold theory to other sectors of education, to doctoral education, to professional learning and even to the social analysis of an entire nation in transition.

Taking this into consideration we feel emboldened to see the consolidation of the characteristics of threshold concepts, and of learning thresholds more generally, that were proposed in a tentative fashion in our seminal paper (Meyer and Land 2003). If viewed as a journey through preliminal, liminal and postliminal states, the features that characterise threshold concepts can now be represented relationally. In such a view the journey towards the acquisition of a threshold concept is seen to be initiated by an encounter with a form of troublesome knowledge in the preliminal state. The troublesome knowledge inherent within the threshold concept serves here as an *instigative* or provocative feature which unsettles prior understanding rendering it fluid, and provoking a state of liminality. Within the liminal state an integration of new knowledge occurs which requires a reconfiguring of the learner's prior conceptual schema and a letting go or discarding of any earlier conceptual stance. This reconfiguration occasions an ontological and an epistemic shift. The integration/reconfiguration and accompanying ontological/epistemic shift can be seen as *reconstitutive* features of the threshold concept. Together these features bring about the required new understanding. As a consequence of this new understanding the learner crosses a conceptual boundary into a new conceptual space and enters a postliminal state in which both learning and the learner are transformed. This is an irreversible transformation and is marked by a changed use of discourse. These latter effects – the crossing of conceptual boundaries, transformation, irreversibility and changed discourse – can be characterised as *consequential* features of the threshold concept. These dynamics are summarised in Figure 1.

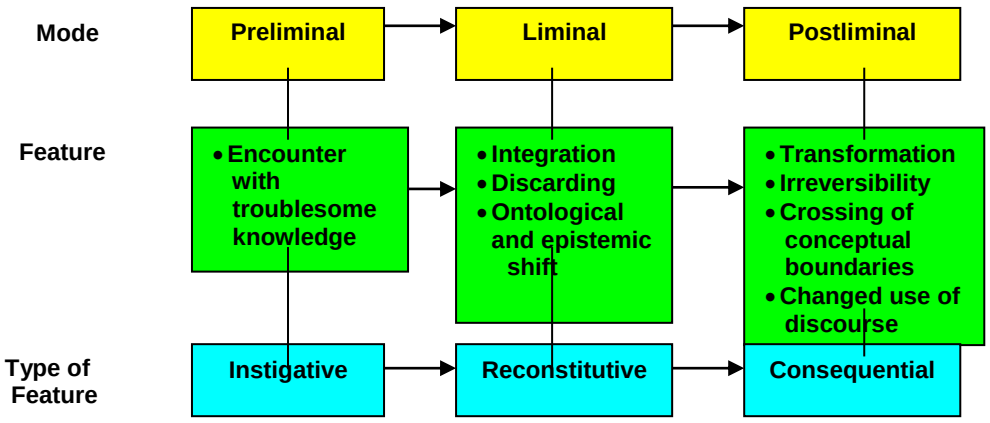


*Fig. 1 A relational view of the features of threshold concepts*

We would not, however, wish to imply that this relational view has an overly rigid sequential nature. We have emphasised elsewhere (Land et al, 2005) that the acquisition of threshold concepts often involves a degree of recursiveness, and of oscillation, which would need to be layered across this simple diagram. Furthermore, running thoughout this transformational process, in what we might term the 'subliminal' mode, there is often an 'underlying game' in which ways of thinking and practising that are often left tacit come to be recognised, grappled with and gradually understood. This underlying game is a common feature of the processes of entry, meaning making and identity formation typically required for entry to a given community of practice.

## TRANSFORMATION

It is the nature and process of this transformation or reconfiguring which this volume particularly seeks to address. A number of resonances can be identified between the thresholds approach and work undertaken in the field of transformational learning. The first seminal paper identified correspondences with Mezirow's work (1978, 1990) on 'perspective transformation'.

> Perspective transformation is the process of becoming critically aware of how and why our presuppositions have come to constrain the way we perceive, understand, and feel about our world; of reformulating these assumptions to permit a more inclusive, discriminating, permeable and integrative perspective; and of making decisions or otherwise acting on these new understandings. (Mezirow, 1990, p.14)

Mezirow saw transformation being triggered by what he termed a 'disorienting dilemma'. In his analysis the meaning schemes that we hold concerning a

particular phenomenon or situation are unsettled by the disorienting dilemma or challenging perspective and occasion a series of phases, often involving a phase of withdrawal or disengagement prior to a re-engagement in which the integration of the different perspective is integrated. We recognise a number of correspondences here with the instigative effect of threshold concepts, the liminal phase of thresholds theory and the process of integration it entails.

A recurring critique of Mezirow's work on perspective transformation, however, has concerned its continued emphasis on the rational and analytic nature of the critical reflection that is seen as a primary driver. Boyd and Myers (Boyd, 1989, 1991; Boyd and Myers, 1988) offer an alternative approach, originating in depth psychology, which balances rational reflection with an emphasis on affective processes. They stress, for example that learners must (affectively) be open to the possibility of transformation in the first place and willing to accommodate 'alternative expressions of meaning' (1988, p. 277). Key phases in the process of transformation as they see it are receptivity, recognition and a final stage of 'grieving' in which there is a recognition that an established pattern of meaning is no longer tenable or valid for future practice. This brings about a point or state of *discernment*. The prevailing perception has to be let go of and eventually discarded so that a process of integration might begin. In their framework this is both a psychological as much a social process and ties with our own view that in the liminal phase an ontological shift or change in subjectivity accompanies change in cognitive understanding, often as part of a\recognition that such shifts are necessary and appropriate for membership of a given community of practice. In our framework the process is also recognised as troublesome and can incur resistance (see particularly Schwartzman, Chapter 2). The shift is also irreversible, a point noted by O'Sullivan and colleagues:

> Transformative learning involves experiencing a deep, structural shift in the basic premises of thought, feelings, and actions. It is a shift of consciousness that dramatically and irreversibly alters our way of being in the world. (O'Sullivan et al, 2002, p. 11)

## METAMORPHOSIS

Kegan (1982) has drawn attention to the ways in which individuals experience such 'shifts of consciousness' through recurring patterns or phases of stability and change during their lives. Julie Timmermans in the opening chapter of this volume points to the elusiveness and inherent difficulty of examining these transitional phases.

> It is these periods of change, these transitions that characterise the learning process, which I find most intriguing. These transitions remain nebulous; however, understanding them is crucial. Cross (1999) notes that 'in developmental theory, the periods of greatest personal growth are thought to lie in the unnamed and poorly-defined periods *between* stages' (p. 262; emphasis in original). We might therefore imagine that the most significant

> aspect of learning lies not in the *outcomes* of learning, but in the *process* of learning. Understanding this process and how best to facilitate it is thus essential to our work as educators. (Timmermans, Chapter 1)

In her novel *Regeneration*, concerning the trauma and rehabilitation of shell-shocked First World War soldiers, Pat Barker offers a striking, if somewhat unsettling image of transformation. Her character Rivers, a military psychiatrist 'knew only too well how often the early stages of change or cure may mimic deterioration. Cut a chrysalis open, and you will find a rotting caterpillar. What you will never find is that mythical creature, half caterpillar, half butterfly, a fit emblem of the human soul, for those whose cast of mind leads them to seek such emblems. No, the process of transformation consists almost entirely of decay' (Barker, 1991. p. 184). The theme of elusiveness in the process is continued here but also the necessity of discarding the former state. As the American-French writer Anais Nin observed, 'To change skins, evolve into new cycles, I feel one has to learn to discard. If one changes internally, one should not continue to live with the same objects. They reflect one's mind and the psyche of yesterday. I throw away what has no dynamic, living use.' (Nin, 1971, p. 26). But as Rebecca Solnit points out, as yet, 'We have not much language to appreciate this phase of decay, this withdrawal, this era of ending that must precede beginning. Nor of the violence of the metamorphosis, which is often spoken of as though it were as graceful as a flower blooming ... The process of transformation consists mostly of decay and then of this crisis when emergence from what came before must be total and abrupt'. (Solnit, 2006, p. 81-3). The chapters that follow in this volume attempt just that, an articulation of what such transformation – literally a going beyond one's extant form – entails. And, as we will see in the following pages, the transformation will always be determined to some extent by its disciplinary, or interdisciplinary, context. As Crainton emphasises:

> Transformative learning is not independent of content, context, or a discipline. It's not an 'add on' to a course. It is a way of making meaning of knowledge in a discipline in a way that students don't passively accept and believe what they are told or what they read, but rather engage in debate, discussion, and critical questioning of the content. Promoting transformative learning is a part of 'covering' content. (Kelly and Crainton, 2009, p. 1)

Transformative learning, she argues, can be promoted by using 'any strategy, activity, or resource that presents students with an alternative point of view'. These might include 'readings from different perspectives, field experiences, videos, role plays, simulations, and asking challenging questions' all of which have the capacity to effect transformative learning. 'The educator needs to create an environment in which critical reflection and questioning norms is supported and encouraged' (ibid). What would seem to be the enemy of transformative learning, however, is didacticism or any form of coercion. This is persuasively expressed by the American theologian and teacher Walter Brueggemann. The elegance of his argument merits quoting in full:

> We now know (or think we know) that human transformation (the way people change) does not happen through didacticism or through excessive certitude but through the playful entertainment of another scripting of reality that may subvert the old given text and its interpretation and lead to the embrace of an alternative text and its redescription of reality. Very few people make important changes in their description of the world abruptly. Most of us linger in wistfulness, notice dissonance between our experience and the old text, and wonder if there is a dimension to it all that has been missed. Most of us will not quickly embrace an alternative that is given us in a coercive way. Such coercion more likely makes us defend the old and, in general, become defensive. Victor Turner noted that there is an in-between time and place in social transformation and relocation, which he termed liminality. Liminality is a time when the old configurations of social reality are increasingly seen to be in jeopardy, but new alternatives are not yet in hand. What we need for such liminality is a safe place in which to host such ambiguity, to notice the tension and unresolve without pressure but with freedom to see and test alternative textings of reality. (Brueggemann, 1995, pp. 319-20).

## EXTENDING THE THEORY

The opening section of this volume contains six chapters which in different ways move forward our thinking about thresholds. **Julie Timmermans** (Chapter 1) situates the characteristics of threshold concepts within a developmental framework. Informed by Kegan's (1982) interdisciplinary Constructive-Developmental Theory and recognising 'the equal dignity' of both cognition and affect, she examines the process of epistemological transformation triggered by threshold concepts. Seeing each stage within the transformational journey as a kind of new (evolutionary) truce, she draws our attention to the nature of the (alternative) 'commitments', both cognitive and emotional, that may be held by learners. These 'may provide educators with rich insight regarding learners' unwillingness to change' and their reluctance to let go of a sense of integrated selfhood. In asking 'What type of learning leads to development?' she draws attention to the 'complex continuum' of emotional responses likely to be found within the liminal space.

> That some learners 'open up,' while others clearly get 'stuck' … may signal to us as educators that the epistemological transition being instigated by a threshold concept lies *beyond* the learner's zone of proximal development (Vygotsky, 1978). That is, it lies too far beyond what the learner may achieve when guided by more skilful others. These variations in response to teaching caution us to be attuned to variations in the ways that learners are making meaning.

In addition to proximal influences this leads her in her conclusion to emphasise the 'multiple layers of context', such as religion and family, that may shape

individuals' epistemic beliefs. In a timely note of caution to discipline-based teachers in their attempts to 'teach' threshold concepts she calls for increased attention to the learning *process* and a tolerance of variation in learners' cognitive and affective responses.

From the perspective of phenomenological analysis **Leslie Schwartzman** (Chapter 2) challenges the current theoretical premises of the threshold concepts framework, arguing for a rigorous transdisciplinary theoretical foundation predicated on the scholarship of rupture in knowing (Heidegger, 1927) and the responses, both reflective and defensive, that might ensue (Segal, 1999l). A more productive approach to understanding how students negotiate and traverse liminal space, she argues, and to how we might better assist them in this activity, is to be found 'in universal human patterns of encounter and response to the existentially unfamiliar (what appears initially as the unknowable unknown' rather than focusing on variations arising from the sundry disciplinary contexts of learning, or from 'individual inadequacies'. Her analysis leads to a significant contrast in how we might define transformational learning as distinct from deep learning. As a result of deep 'cumulative' learning, she argues:

> one switches dynamically – within the same field of consciousness – among thematic foci, with correspondent restructuring of thematic fields (Booth, 1997 p.144). The total set of elements in the field remains constant, while boundaries among the thematic focus, the thematic field, and the margin become fluid; and component elements shift between adjacent domains. The mechanism of dynamic switching among extant elements corresponds to *reflection*; *the operation corresponds to refinement and clarification of one's extant meaning frame*. (Editors' italics).

In contrast, the outcome of transformative learning, she contends, is that:

> the contents of the field of consciousness change. Elements formerly not found in any domain of consciousness, possibly including component parts of elements formerly classified as non-decomposable, now occupy the thematic focus or reside in the thematic field; and some elements formerly found there are now relegated to the margin. The mechanism remains mysterious and corresponds to *reflectiveness*; *the operation, which results in a different population in the field of consciousness, corresponds to reformulation of one's meaning frame*. (Editors' italics).

In clarifying this nice distinction, she questions whether the proponents of threshold concepts in their teaching are adopting the latter approach, bringing new meaning to bear upon existing experience (which the Meyer and Land framework would seem to condone), or the former approach, which would seem to be attempting the reverse.

The nature of troublesome knowledge is given a further dimension in **Aidan Ricketts**' application of the threshold concepts framework to the teaching of Law (Chapter 3). In relation to transformational learning he points out that

'transformative experiences may enhance a student's critical awareness, but this should not be assumed; in some cases the nature of the transformation may actually reduce the scope for critical thinking. He coins the term 'loaded knowledge' to refer to the manner in which increased access to and facility with the ways of thinking and practising of a given community of practice (in this case the legal profession) may have a reductive effect more generally in terms of occluding other forms of knowing. The particular instance given here is the way in which students of legal education might find access to certain forms of critical knowing difficult within their curriculum. This is not inevitable but the practice of legal education needs to be carefully designed, he argues, to ensure the inclusion of critical perspectives, including critique of 'the very discipline they have come to study'. In a study of much wider applicability to all disciplines he concludes that it 'appears inevitable that studying law will involve encounters with troublesome and counter intuitive ideas and with loaded knowledge and that one way or another law students are likely to be changed by the experience. The challenge for educators, is to decide whether education should be openly self critical even of its own discipline or simply impose closed intellectual and value systems upon its students.'

If the troublesome transformations occasioned by threshold concepts require a rather different way of looking at the curriculum, then it follows that such transformations will require a more nuanced and generative model of assessment. This would help us identify variation in progress and understanding at the preliminal, liminal, postliminal and subliminal stages of conceptual and epistemological fluency. **Ray Land** and **Jan Meyer** (Chapter 4) argue for a dynamic model of assessment, acting more like a 'flickering movie' of a student's progress along the transformational journey and indicating how structures of a student's understanding might be changing rather than a stationary, one-off 'snapshot'. In a framework such as threshold concepts that points to the variation in progressive stages of a student's journey towards, through and beyond particular conceptual gateways they ask how we might construct a meaningful assessment process for students for whom, in many instances, what is to be assessed lies outside their prior knowledge and experience, or beyond their ontological horizon. The threshold concept has not fully 'come into view'. This might move us on from traditional assessment regimes in which a student seems to be able to produce the 'right' answer while retaining fundamental misconceptions. They seek an insightful conceptual basis for developing new and creative methods of assessment and alternative ways of rendering learning (and conceptual difficulty) visible. This in turn can inform course (re)design in a generative and sustainable fashion.

**Ian Kinchin, Lyndon Cabot** and **David Hay** (Chapter 5) demonstrate the kind of approach Land and Meyer advocate, as a means of rendering learning and patterns of understanding 'visible' in professional clinical settings such as dentistry, medicine and nursing. In a piece entitled 'Visualising expertise' they too seek a quality of dynamism – 'a dynamic transformation of knowledge structures, relating competence and comprehension'. They represent the gradual transformation of learners' understanding through concept mapping techniques that render explicit current states of knowing and conceptual linkages that can be

represented by 'chains' of practice and 'networks' of understanding. Over a given period of time the structures of meaning-making can be seen to change, with new elements being integrated, others being let go of or discarded, whilst further elements enter understanding but remain unintegrated. In affective terms however, the adoption of expertise-based pedagogy, requires a certain confidence and courage on the part of teachers and practitioners both to share their knowledge, and the gaps in. This approach often surfaces understandings and misunderstandings which previously might have remained tacit. 'The knowledge structures approach, facilitated by concept mapping tools', the authors contend, 'provides a mechanism to go beyond making learning visible, towards making it tangible (i.e. not only can it been seen, but it can also be manipulated to support development).'

To conclude the opening section on theoretical aspects of threshold concepts **Jerry Mead** and **Simon Gray** (Chapter 6) focus attention on the use of the term *concept* in thresholds parlance in order 'to provide a more secure footing, in the form of a model of conceptual structure on which the term "concept' in "threshold concept" can rest'. They address this issue from a disciplinary perspective, viewing the identification of threshold concepts as something reached consensually over time within the disciplinary community – 'disciplinary constructs that have emerged from the crucible of disciplinary scrutiny as definable abstractions' and with any personal connotations discarded. Hence the role of an educator within a given discipline is to align the structure of students' evolving *personal* conceptions with that of the agreed *disciplinary* conception. They point out that the personal effect of threshold concepts on learners can only be significant 'if the way someone thinks from inside a discipline is different from the way someone outside of the discipline thinks'. But here they take issue with the current threshold concept definition pointing out that 'it leaves threshold concepts isolated from an ontological point of view' without reference, from the student perspective, to other concepts in its disciplinary context. As they put it, 'the idea that a threshold concept "exposes the previously hidden interrelatedness of something" implies that there must be other relevant concepts, i.e., the things that are "interrelated.''.

To address this they set out to provide, within a disciplinary context, a conceptual structure, a 'more secure footing', within which threshold concepts 'can be localized'. They employ Perkins' notion of a *concept episteme* as 'the system of ideas or way of understanding that allows us to establish knowledge of the concept'. They name the kind of conceptual structure they produce a 'disciplinary concept graph' (DCG). This can facilitate student understanding of concepts in a discipline, and, they argue further, the five threshold concept characteristics can be localized within such concept graphs. Using atomic theory as illustration, they seek to identify the concepts that are central to a discipline and which serve as the 'targets of the questions, problems, and judgements' that arise in that discipline. They coin the term *condensation point* to encapsulate 'a unifying and generalizing concept that is definable within an episteme and condenses out of the associated knowledge space a fundamental disciplinary idea or capability'.

## CONCEPTUAL TRANSFORMATIONS

The central section of the volume offers a rich variety of instances of important transformations within the learning of particular disciplines and demonstrates how tutors have tried to understand the kinds of conceptual difficulty faced by their students. In the geosciences **Kim Cheek** (Chapter 7) discusses three possible factors that account for why the notion of 'deep time' proves so troublesome for learners, namely conceptions of conventional time, understanding of large numbers and the student's current state of subject knowledge. She points out the alien and counter-intuitive understanding involved in grasping 'that rocks can behave plastically, continents move, and the mountains we visit will one day be gone'. Much of this difficulty stems from the fact that though deep time is not a qualitatively different construct from a general concept of (conventional) time , it nonetheless requires a logical extrapolation 'to events and processes that are out of the realm of human experience by orders of magnitude'. The processes involved occur at very slow rates and hence are imperceptible to human observers. Such temporal understanding is not within the horizon of the student's experience and neither is the scale of the numbers necessary for such understanding. Issues of scale require an ability to work in different units of measure. The capacity to work in a unit of millions of years, and to differentiate a million year unit from a thousand year unit, 'enables a person to meaningfully conceive of many geologic processes'. However even adults, it seems, will resort to a more logarithmic scale (as opposed to linear mapping) when confronted with such large numbers. A subtle and potentially complex effect arises from the student's prior subject matter knowledge, and their prevailing ways of thinking and practising, i.e. can a student place a particular species in a sequence of events if she doesn't know what it is?

> We may be inferring an understanding (or lack thereof) about deep time when it's really something else directly related to specific geologic knowledge [or even analogical reasoning from some other subject area with which the student is familiar] that's accounting for student responses.

In Chapter 8 **Monica Cowart**, a philosopher, seeks an explanation of 'how to identify, deconstruct, and integrate philosophy-specific threshold concepts so that students can develop disciplinary specific thinking'. What does it mean, she asks, to think like a philosopher? What languages games, rituals, customs and methods come into play? An awareness of threshold concepts, she argues, can guide the decisions professors have to make in terms of prioritising what should be taught in philosophy programmes, how it should be taught and how it might be best assessed. She maintains that philosophy's three sub-disciplines of ethics, epistemology, and metaphysics are the key to recognizing 'core' threshold concepts within the discipline. These core philosophical threshold concepts exist at the *intersection* of the three sub-disciplines because these concepts raise questions within each sub-discipline. This positioning is significant as:

> to truly have an understanding of core philosophical threshold concept x, you must understand the questions threshold concept x raises in metaphysics, ethics, and epistemology. To simply understand the questions the concept

raises in only one of these areas will not result in an accurate understanding of the concept.

The location of the concept at the intersection however, adds to its complexity, and hence potential troublesomeness to students. The author examines a specific example of such an intersectional threshold concept in the notion of 'personhood', before moving, in the second part of the chapter, to consider how this concept might be taught and learned. Utilising the specific epistemes (or philosophers' tools) of thought experiments, the Socratic method, and analytic deconstruction, she outlines a pedagogical approach to the teaching and learning of personhood predicated on principles of active learning. This involves the preparation of and participation within a formal team debate and includes the design of an assignment 'that will enable students to showcase in the public domain knowledge of personhood through the rule-governed use of the discipline-specific epistemes, which enable the exploration of the concept'.

Questions of intersection and the importance of prior learning raised earlier by Kim Cheek, occur again in Chapter 9 where **Rosanne Quinnell** and **Rachel Thompson** consider the points where students are likely to encounter difficulty as they practise academic numeracy in the life sciences and medical statistics. Far from being a transferable skill, numeracy, they suggest, for many students in their field, can become a transferable anxiety. 'A grasp of numeracy is essential to understand the abstraction of the biological phenomenon; failure to appreciate that patterns in biology can be represented in abstracted mathematical forms inhibits students' understanding of scientific practice'. The authors present an experiential learning cycle in science that mirrors their practice of attempting to understand biological phenomena. They map on to this cycle where numeracy and literacy skills intersect, and the points at which they observe that student engagement begins to wane, 'the moments when students experience obstacles to learning'. It emerged that 'most of these points of uncoupling involved numbers and formulae', leading the authors to infer that 'for numerophobic students, this is a key factor affecting student progress through the liminal space in understanding a threshold concept'. Following a process of *unpicking* of numeracy issues based on tutors' and students' experience, the authors identify three main overarching threshold concepts in statistics within their field – the 'sampling distribution' lens, the 'strength of evidence' lens (including hypothesis formation and testing), and the 'applicability of evidence' lens – with the associated basic and threshold concepts that underpin each of these. Two case studies are described in which interventions were made to help students cope with these learning thresholds and overcome anxieties regarding numeracy. In the first the need to explain the concepts using numbers was removed, and with it the concomitant numerophobia, and students were enabled 'to find another route through this difficult learning moment'. In the second study tutorials were constructed around a 'numeracy diagnostic' focused on confidence. The aim of this diagnostic was to pinpoint where numeracy was problematic and where students were uncoupling themselves from the learning process. Interestingly the students who engaged most fully with this challenging

task were those least confident in their responses. Both of these approaches have proved fruitful in identifying future paths for skills development and overcoming barriers.

Two further chapters in this section also examine threshold concepts within biological sciences. **Pauline Ross** and her colleagues **Charlotte Taylor, Chris Hughes, Michelle Kofod, Noel Whitaker, Louise Lutze-Mann** and **Vicky Tzioumis** (Chapter 10) explore the nature of student misconceptions in biology. A range of candidates are identified as potentially troublesome content knowledge, including cellular metabolic processes (e.g. photosynthesis and respiration), cellular size and dimensionality (surface area to volume ratio), water movement (diffusion and osmosis) genetics (protein synthesis, cell division, DNA) evolution, homeostasis and equilibrium. In addition to this however the authors identify a number of procedural threshold concepts such as energy, variation, randomness and probability, proportional reasoning, spatial and temporal scales, and thinking at a submicroscopic level. Students lack of such procedural or processual abilities, compounds the inherent difficulty in the subject content knowledge, causing misconceptions. The authors argue that employing thresholds as a heuristic in this fashion permits insights not gained from the existing misconception and constructivist literature and raises a number of questions for the development of teaching and learning in biology. On the assumption that threshold concepts reflect differences in ways of thinking and practising between acknowledged experts inside the subject and novices on the periphery, they argue that students should be encouraged to acquire facility with the procedural thresholds mentioned above to facilitate their crossing of portals and hence develop a better understanding of hitherto troublesome knowledge. This will enable us to understand 'whether students can subsequently transfer this thinking process to aid their understanding of other similarly difficult content (that is, to see if they have learnt how to cross unfamiliar thresholds)'.

Within biological sciences the capacity to formulate an experimental design and a testable hypothesis within it can be seen as a crucial aspect of how biologists 'think'. **Charlotte Taylor** and **Jan Meyer** (Chapter 11) investigate the processes through which students acquire this capacity for 'apprehending the multivariate complexity of the biological world and hypothesising within it phenomena amenable to experimental verification'. In keeping with threshold theory this apprehension contains an *ontological* dimension and its own *discursive* modes of 'reasoning and explanation'. The authors point out that although higher order abstract dimensions of biological thinking are an indispensable part of this process, and that in discursive terms, 'the mechanics of defining a precisely worded testable hypothesis require an appreciation of the appropriate language and symbolic representations', nonetheless these requirements can to some extent be acquired in a rote manner, with testing procedures for the hypothesis gained through recipe-like formulae. It is the *integration* of ideas, they suggest, which is key, and which:

> demonstrates a transformed understanding, requires a sophisticated articulation of the scale, dynamics, complexity, variability and role of

> probability in explaining the system under investigation. Dealing with this in the paradigm of scientific thinking encompasses the threshold.

These concerns have led to a consideration of the experience of students in the preliminal space. The students often have limited prior experience of the complexity of biological systems, and encounter scenarios and processes not easily amenable to observation at the molecular or chemical level. Engagement and ownership become the critical factors, with a need for students 'to have the opportunity to take ownership of the process of observation, explanation and hypothesis creation, for successful understanding to occur.' The rich sources of data from students' thinking, as they engage in the process of hypothesising and document their move into the liminal phase, signal the need for significant changes in our approaches to the teaching of biology.

Through a careful analysis of written answers by students in economics examinations **Peter Davies** and **Jean Mangan** (Chapter 12) consider the role of threshold concepts in assessing the progression of students' understanding in economics. Drawing on both threshold theory and variation theory ((Pang and Marton, 2005) they argue that the conception of a phenomenon that is described by a basic concept within a discipline can 'only be attained once a learner is able to use a super-ordinate threshold concept to organise their conceptual structure'. However, for learners to be able to organise their thinking through a threshold concept, they continue, they will also need to use certain associated 'procedural concepts'. As they put it:

> If a discipline threshold can be represented as a 'portal', then procedural concepts provide the means by which the structural form of the portal can be assembled: the guidance that directs the way in which pieces are put together.

Taking an example from economics they argue that without a 'modelling' (or procedural) concept of equilibrium, the set of basic concepts needed to grasp a model of the determination of the level of national income – concepts such as the distinction between injections and withdrawals, savings and investment, stocks and flows, real and nominal values – cannot be made 'to act in concert to produce a coherently structured understanding of an economy as a system'. On the other hand, they suggest, if a student *is* observed to be employing a modelling concept in this way to mobilise one or more basic concepts, then it is probably reasonable to infer that he or she is engaging in the process that can lead them towards incorporating a threshold concept.

The authors' proposition that 'more complex conceptions of a phenomenon rely on the transformation of basic concepts by disciplinary threshold concepts that integrate a learner's conceptual structure' gives rise to significant assessment issues in a massified system of higher education where tutors are faced with large numbers of scripts and seek salient cues to student understanding as a kind of shorthand to facilitate speedier techniques of marking in large first and second year classes. This can prove dysfunctional however. The authors predict that, for example:

> when students are introduced to a concept like 'the circular flow of income' they begin to use the language of a disciplinary conception (such as 'multiplier') well before they have developed the kind of understanding which an expert might infer from use of such terms. This creates an assessment difficulty in the context of 'large-scale' assessment.

The model of the development of a threshold concept provided by the authors here identifies the understanding of procedural concepts, such as equilibrium mentioned earlier, as critical. The evidence gained so far in this enquiry points to this conclusion, though there is a need for further empirical study to confirm these findings.

In a further empirical study drawn from economics **Martin Shanahan, Gigi Foster** and **Jan Meyer** (Chapter 13) build on the earlier observation by Meyer and Land (2006) that individuals proceed at varying rates across conceptual thresholds and exhibit varying states of liminality. These authors also utilise a combination of threshold theory and variation theory to assess the degree of tacit knowledge that students bring to a threshold concept in the preliminal state, for, as with prior content knowledge, students may vary greatly in the amount of prior tacit knowledge they have of particular threshold concepts. The authors then tread new ground in researching whether an association exists between threshold concept understanding and *attrition* from a course of study. The focus of their study is an examination of the correlation between students' observed grasp of certain threshold concepts in economics at the start of a semester and their likelihood of leaving an introductory microeconomics course in that same semester. An interesting secondary consideration of their study is the hypothesis that an important ontological shift is also required on the part of students – a shift in which one comes to view oneself as a bona-fide student learner – as 'a necessary preliminary stage of thinking that must be attained by students before discipline threshold concepts become relevant'. In terms of attrition they speculate that it is the students who fail to make this shift that are the most likely to leave the course early. Moreover, they suggest that 'the impact of pre-liminal knowledge of economic threshold concepts is only relevant once this transformation is made'. The findings of the enquiry lead the authors to believe that, though the factors associated with student attrition are many, an important conceptual portal that many students must negotiate as a mark of commitment to their studies is that of 'self-identification as a university student'. An interesting secondary finding is that, once a student has committed to study (roughly completion of the first semester of teaching), then variation in students' grasp of discipline-based threshold concepts may be associated with an individuals' preparedness to sit the exam. Self-identification as a university learner is a clear determinant of student retention in these findings, although, as the authors indicate, 'the distribution of previously acquired threshold concepts does appear to be systematically related to other differences that place students at risk of failing'.

Professor Ference Marton, a leading proponent of variation theory, recently commented that:

> The one single thing that would improve the quality of teaching and learning in higher education would be if academics in different disciplines took time

> to meet together and discuss what they should be teaching in their subject, and how they should be teaching it. This is something that Variation Theory has not done, and I think the Threshold Concepts approach encourages people to do this. In my opinion there is absolute complementarity between Threshold Concepts and Variation Theory. (Marton 2009).

In a significant example of academic specialists engaging in exactly such a conversation, and also reaching conclusions on the possible complementarity between Threshold Concepts and Variation Theory**, Michael Flanagan, Philip Taylor** and **Jan Meyer** (Chapter 14) examine the ways in which 'transmission lines', a threshold concept in electrical engineering may come into view quite differently depending on whether the concept is introduced from a perspective of large-scale systems (power engineering) or small-scale systems (instrumentation and electronics) and whether students are envisaging power transmission along overhead power lines or along TV and computer cables. . In experimental tests in the former, students struggled with the notion of *reactive power*. As a complex idea of what is in effect 'powerless power', requiring the use of (imaginary) complex number, students found this both counter-intuitive and 'mentally awkward'. With small-scale systems students struggled similarly with the idea of *characteristic impedance*. Students in both engineering contexts were left frustrated, perplexed and confused, and, as we have seen elsewhere in threshold analyses, resorted to 'mimicry' as a coping strategy. For some students, the authors point out, it became clear that 'elaborating the simpler concept of current flow down a wire into a mathematical treatment of the associated electromagnetic field was troublesome and counter-intuitive especially as the concept of the electric or magnetic field itself is troublesome'. Indeed, to exacerbate the problem, the authors comment that 'fields' may operate as threshold concepts in their own right. One source of the conceptual difficulty was that the students found it difficult 'to envisage any associated physical reality in the calculations of the properties of a travelling electromagnetic wave (the signal travelling along the line) using complex arithmetic'. In terms of a 'spiral curriculum' (Bruner, 1960), and an analysis of how earlier preparation in the simplified equations of high school physics might have adversely affected subsequent coping with a more complex university curriculum, the authors conclude that such earlier learning presented three potential barriers to learning. Firstly, the concrete had preceded the abstract; secondly, the detailed had preceded the general; and thirdly, perception was now preceding cognition. The authors view was that each of these concepts of reactive power and characteristic impedance were in fact acting as portals to usher students into a far more complex liminal space involving understanding of electromagnetic theory. A number of issues follow from this. One practical problem is that students are not in a position realistically to experiment with such large-scale systems. Though recent computer simulation packages open up interesting and potentially helpful possibilities in this regard there is the danger of students performing calculations in a 'ritualistic' fashion without understanding (Perkins, 1999).

Moreover, in relation to possible complementarity between threshold concepts and variation theory the authors observe that:

> If a troublesome concept is flagged by students and/or staff that is, in reality, a portal to a much more complex liminal space there is a risk that a variational approach constructed around this troublesome concept alone may not effectively aide the students in mastering their difficulties.

In terms of the kinds of knowledge that engineering students should encounter during an engineering degree, the study of learning thresholds in relation to electromagnetic theory raises more far-reaching issues of where applied physics might end and electronic engineering begin, and whether engineering graduates are defined by their skills or their particular industry.

In Chapter 15 we encounter another 'disciplinary conversation' taking place. **Lynda Thomas,** with her colleagues **Jonas Boustedt, Anna Eckerdal, Robert McCartney, Jan Erik Moström, Kate Sanders** and **Carol Zander,** report on the findings of a multi-national, multi-institutional project that has now been under way for four years and which is seeking an empirical identification of threshold concepts in the fast-moving and ever-changing domain of computer science. This systematic and detailed enquiry has evolved to date through five phases of enquiry, embarking initially on an extensive review of the computing curriculum literature, and direct interviews with teachers of computing. The characteristics originally identified by Meyer and Land (2003) were employed as the focus of research questions. This shifted in the second phase to interviewing students nearing graduation on their experience of two main threshold concepts of *object-orientation* and *pointers.* As the students' responses tended to emphasise difficulty, a subsequent research question explored the strategies used by students to become 'unstuck'. This opened up a third phase of enquiry, examining the nature of liminality in terms of the student experience of these troublesome concepts. In the fourth, the methodology shifted to the use of conceptual mapping in order to render visible and better gauge the students' understanding of the central ideas of object-orientation, and of what the students themselves regarded as central priorities. The most recent phase, very much in keeping with the theme of this volume, has analysed student biographies to illuminate the transformative aspect of threshold concepts. Here students were asked to identify and describe a computing concept that 'transformed the way they see and experience computing'. The use of 'lure stories' (Schulte and Knoblesdorf, 2007) brought into view a number of other potential thresholds, many of which are related to the key computing science theme of *abstraction*, and which threw light on how the overall concept of abstraction is manifested in students' learning. The authors' point however that

> whether abstraction is a threshold concept; contrary to expectation, it seems unlikely. Rather, it seems likely that there are a number of threshold concepts in computing that could be classified as abstractions of one form or another.

The student biographies, taken from students in three different countries, identified a range of potential candidates for concepts that had transformative potential. These included *modularity, data abstraction, object-orientation, code*

*re-use, design patterns,* and *complexity*. The authors concluded from this wide ranging and large study that changing their data-collection techniques had affected their results. In the light of the link with variation theory discussed earlier they also found considerable individual variability in student experience, and that the students described more specific thresholds than instructors. In a statement which has interesting implications for those researching transformation and learning thresholds in other disciplines the authors found that:

> Whether or not students experience different thresholds, they place greater significance on different transformations. We observed many potential threshold concepts a single time each; we observed some that seemed highly dependent on a particular context. Coming up with an exhaustive 'catalogue' of threshold concepts in a discipline may be impractical. More important, the sequences of partial understandings that students exhibited as they were learning a concept were quite variable: no single path. Rather than seeing a progression of deeper understandings in a concept, we saw different levels of understandings of different parts.

**Eun-Jung Park** and **Greg Light** (Chapter 16) sought to identify a threshold concept, in studies at the atomic and molecular levels in the relatively new field of nanoscience. Their study (after Davies, 2006) adopted both top-down (expert-focused) and bottom-up (student-focused) methods. These methods included 'the construction of concept maps and an interview with the expert (professor), and the construction of pre- and post- course concept maps and the completion of a linked open-ended survey by the students'. Interestingly both methods tended to converge on one particular potential threshold concept, *surface area-to-volume ratio*, as a candidate for nanoscience, at least within this taught programme. Of this threshold concept the expert professor commented:

> Well, *surface-to-volume ratio* is the threshold concept, because you can't get down here (the nano level) without accepting the fact that really tiny particles have large surface-to-volume ratio… So take a gram of something and keep chopping it up until you get down to nano-particles. And what you see is the surface area just goes through the roof. So this is enabling... because, without that, you can't do this. So this would be a threshold concept.

The professor also identified eleven key, or important, concepts within this field. The survey of forty-two student pre- and post-course concept maps revealed thirty-eight further concepts, in addition to the professor's original eleven. The authors employed a phenomenographic approach to analyse the experiential component of these maps to identify variation in the ways students experienced the troublesomeness of the concept. This revealed 'a hierarchical continuum of patterns of understanding, each more complex and inclusive of the preceding patterns' which produced an outcome space comprising the following five patterns of student understanding: 1. Isolated, 2. Unconnected, 3. Detached, 4. Limited, and 5. Integrated. The key aspect of variation characterising the most complex pattern ('Integrated'), and the pattern most closely reflecting the expert's pattern, was the

recognition of the central role of *surface area-to-volume ratio* in the integration of the key nano domain concepts. Both expert and student responses reported this as an integrative concept, whilst two thirds of the students selecting this threshold concept also experienced a change of understanding during the course towards a more sophisticated pattern. In consequence the authors conclude that their study presents 'preliminary evidence that a meaningful understanding of s*urface area-to-volume ratio* critically contributes to students' ability to integrate other key concepts in the nano-domain'.

Interestingly, however, the concept *surface area-to-volume ratio*, though selected as a threshold, was not regarded as a particularly troublesome or difficult concept to understand. The authors suggest this might be owing to the fact that 'troublesomeness does not necessarily reside directly with the threshold concept but rather in the integration of the domain cluster of concepts within the student's understanding'.

They also report that the representation of student understanding gained from concept maps, though useful, is not a sufficiently rich source of data in itself for analysis and interpretation of student understanding, and their ongoing study will employ subsequent use of interview data.

In the final illustration of conceptual transformation **Marina Orsini-Jones** (Chapter 17) addresses a threshold concept frequently encountered by languages students. This is 'the overarching structure of a sentence', often referred to in linguistics as the *rank scale concept*. The overall concept is formed from acquisition of a range of grammar categories; students must master each of these fundamental grammar 'milestones' before being able to grasp the overall concept. The author proposes that 'encouraging students to actively engage with metacognition relating to the threshold concept identified while they are in the liminal state can also contribute to their "readiness" to cross it'. The data for the study was drawn from a two-year action research analysis which highlighted that many languages students experience 'grammar anxiety', despite the aspirations of many of the group to become English as a Foreign Language (EFL) or Modern Languages (ML) teachers, who routinely have to explain grammar to their students.

Active engagement with metacognition relating to grammar anxiety and the *rank scale concept* was fostered through the design of a 'metareflective socio-collaborative assessed task' to help students overcome the troublesome knowledge, though, the author acknowledges, 'it remains a contested notion whether or not engaging in metacognitive grammatical activities can enhance language learning and whether or not a focus on linguistic form can benefit language skills in the target language studied'. The assessed task, *The Group Grammar Project*, is complex and involves students in a range of activities including web site development, group presentation, anonymous self- and peer-assessment, and the writing of an individual reflective report on the project. In both years of the action research it emerged that the most troublesome elements in the overall *rank scale* threshold concept tended to be complex sentences (relationships and identification of verbs); clauses (identifying subject-verb-object); phrases (confusion with clauses); and word classification (adverbs and prepositions). Barriers to learning the threshold concept included unfamiliar terminology that invoked student

resistance and conservatism, prior (mis)knowledge of terms, requiring an 'undoing' of pre-conceived definitions of the grammar categories involved, prior knowledge, reliance in group work upon peers who found the grammatical categories 'troublesome' but decided nevertheless to take a lead in the analysis of the sentences, misunderstanding of the concepts and lack of ability to ask lecturers for help; lack of motivation towards grammar and the module, lack of reinforcement or support by other tutors teaching languages, and feelings of grammar fear or inadequacy. Lack of awareness of underlying grammar principles emerged as the main concern for the students interviewed, particularly the native English ones. However, a range of strategies were identified as assisting students overcome the difficulty in understanding the rank scale concept. These included collaborative group work; demonstrating initiative and asking for help; confidence building via grammar analysis; practice via diagnostic tests; inspiration from peers; explaining grammar to peers; tailor-made materials, having fun with grammar, and metacognition. In these ways the *Group Grammar Project* seems to have improved grammar knowledge and confidence for most students.

> It would seem that the increase in the amount of work done at the 'metareflective' level improved the students' ability for accurate self-assessment in grammar understanding. It could be argued that this in turn had enhanced there 'preparedness' to embrace the ontological shift necessary to cross the threshold. It could be argued that metareflection encouraged students to engage with their state of liminality towards the threshold identified in a positive and constructive way and helped with overcoming the paralysing 'fear of grammar' some had experienced at the beginning of the academic year.

Compared with the ease with which the majority of native French, German, Polish and Italian students, (who had been familiar with formal grammar teaching since primary school) tackled the analysis of the grammar categories, however, many negative attitudes towards grammar arising from the English school system proved difficult to 'undo'. The European students did not perceive the grammar analysis of sentences in the assessed task as a 'terrifying' task like so many of their English counterparts. The author further concluded that the study had confirmed that a learning threshold of such complexity as the *rank scale concept* could not be adequately crossed in one year by many students.

## ONTOLOGICALTRANSFORMATIONS

The concluding section of the volume presents illustrations of the ontological transformations mentioned earlier in this chapter. These 'learning thresholds' might not be strictly conceptual but seem necessarily occasioned by significant learning and are more concerned with shifts in identity and subjectivity, with procedural knowledge, or the ways of thinking and practising customary to a given disciplinary or professional community. An underlying implication here is that there is always some form of self-relational trajectory to the discipline being

learned (Cousin 2009). We are a student and practiser of music in order to become a performing pianist. Being and knowing are inextricably linked. We are what we know, and we become what we learn. As Davies (2006) has pointed out, an act of learning is an act of identity formation.

In Chapter 18 **Jens Kabo** and **Caroline Baillie** examine one such ontological shift required by students of engineering when encountering engineering's relationship with social justice. For much of their engineering education the students envisage their future development and practice as likely to comprise 'problem solving, technical development, efficiency, and profit making'. This 'common sense view', the authors suggest, is likely to be predicated on an 'inherent belief that technical development always equates to progress'. However such a perspective is now open to the challenge that rapidly accelerating technological advances and interventions are implicated in the rise of serious global challenges such as poverty and environmental sustainability (Catalano 2007). The production of biofuels, for example, though encouraged to counter global warming, has occasioned the unintended consequences of increases in food prices and the destruction of rainforests. The critical perspective of 'who benefits and who pays' hence becomes a necessary consideration in the reasoning and judgement of engineers. However, as these authors note, 'the established ways of thinking within a community or a group can serve as barriers toward new knowledge building, i.e. potentially create thresholds.' The 'thought collective' that the engineering students had entered, one of the authors found when teaching a course on social justice, seemed to constitute such a threshold. As students encountered the learning threshold of social justice they seemed to adopt the oscillative behaviour characteristic of liminal states. Students taking the course 'appeared to move into a liminal space, some passing through, some getting stuck and others moving back and forth uncertain of what to do.' For both experienced and novice engineers the required adoption of a socially just perspective to their practice and profession appeared to provoke a 'transformative and troublesome' state of liminality. The authors adapted the phenomenographic framework of Marton and Booth (1997) to assess variation in the response of learners to understanding and integrating the notion of social justice.

> A key thing that varies over the different conceptions is the students' awareness of the complexities surrounding social justice, which goes from simple and superficial to complex and deep. Other shifts are from active to passive and individual to collective.

The outcome space achieved through this approach produced nine conceptions of social justice, ranging from a pre-liminal state of virtually no understanding, through a (liminal) moral awareness of social justice as duty and responsibility, to a more sophisticated recognition of social justice as a participatory undertaking, and on to a post-liminal capacity to employ social justice 'as a lens for deconstruction and critical analysis'. The authors stress however that the nine conceptions are not to be seen as a linear progression 'since they both overlap and can exist simultaneously in how a student views social justice'. The barriers to

understanding and progression were found to be often ontological, requiring a letting go of taken for granted collective cultural assumptions that engineering tends to be focused on money, profit making and efficiency rather than social justice. At the level of individual response, the learning threshold required 'sacrifice, risks, doubts and discomfort' and difficulty in moving 'beyond the things they took for granted'. As one student commented:

> [The course] really messed with my head. Sometimes I was scared going to class because I didn't want to think about stuff. [...] it put some guilt on my actions [...] I feel that it might have an impact on my success in a company, for example if I don't do it the next person might.

In her work with colleagues on the Freshman Learning Project at Indiana University **Leah Shopkow** (Chapter 19) has encountered this kind of learning threshold, or as they term it, a conceptual 'bottleneck' or 'impasse' in understanding, across many disciplines. The difficulty may lie in '"basic" concepts, some of which may be threshold concepts, others of which may be clusters of threshold concepts, and some of which constitute disciplinary ways of knowing'. In a separate but parallel project to the development of thresholds theory, but with a similar chronology, her colleagues have developed an approach to assist colleagues in 'decoding' their disciplines in order to become 'more mindful teachers' and hence more able to assist their students through these learning bottlenecks. She describes the work of Decoding the Disciplines (DtD) as follows:

> DtD approaches the problem of impasses in student learning not from a theoretical perspective (although theory is quite useful in grounding its practices), but from a practical approach that emphasizes both the modelling of expert behaviour for students and the explicit explication of its underlying epistemes; the expert is rendered more self-conscious about these epistemes through a metacognitive dialogue between the expert and interviewers not necessarily within the expert's discipline.

She suggests that the DtD methodology can facilitate the application of the theory of Threshold Concepts in five ways. First of these is that it can help 'identify and order concepts and understandings ...where even the notion of essential concepts can be contested'. This often can apply in the Arts and Humanities, and History is examined here as a particular illustration. The range of learning thresholds identified within this discipline indicates how the conceptual and ontological are inextricably linked, and includes, to take a sample, developing and evaluating historical arguments, recreating historical context, maintaining emotional distance, overcoming affective roadblocks, willingness to wait for an answer, dealing with ambiguity, seeing artefacts from the past as representing choices that change over time, identifying with people in another time/place, understanding historical change, reading critically, writing historically, using appropriate language, and understanding notions of time. Secondly the author

agues for the value of DtD in helping to surface tacit knowledge and render it more accessible. The latter she argues is a form of troublesome knowledge 'both drawn upon and expected by the teacher' and which students otherwise merely have to intuit. Her third point relates to the teacher's own academic subjectivity in relation to pedagogy and the greater possibility of engaging discipline-focused academics in considering the difficulties in understanding faced by their students. 'Because the methodology uses as its launching pad the instructor's own disciplinary modes of thought and teaching concerns', the author contends, it is less likely to be perceived as alien knowledge or foreign knowledge by the instructor'. This is in keeping with the point often made by Professor Glynis Cousin that the thresholds approach invites disciplinary academics 'to deconstruct their subject, rather than their educative practice, thus leaving them within both safe and interesting territory' (Cousin, 2007; see also Flanagan, Taylor and Meyer, and also Weil and McGuigan, in this volume). A further and fourth point made by the author is that because the DtD approach helps clarify both the intended learning outcomes of the teacher and also where barriers to student understanding might lie, the process of course (re)design is made easier, as is also the means of evaluating whether students have achieved the intended learning. This then, in turn, 'provides guidance for interventions'. Her final point raises the important issue of how learning thresholds might be addressed across the span of an entire curriculum lasting for several years. This requires a collaborative engagement at departmental or even institutional level.

> No one faculty member is equally suited or has the kind of continuity of instruction with individuals to help students negotiate them all. If we want students not still to think like novices at the end of their undergraduate programs as they often still do (for a case in History, see Wineburg 2001), many faculty members will have to work collectively to this end. We will have to think about how Threshold Concepts might be sequenced in disciplines, like History, where the content is not sequenced of itself, so as to introduce students to these concepts in a systematic way, to ensure that students keep using the concepts to prevent student knowledge from becoming inert, and to help students learn to coordinate all the concepts that define the epistemes of the disciplines.

**Sidney Weil** and **Nicholas McGuigan** (Chapter 20) also take up the notion of epistemes, characterised by Perkins (2006, p.42) as 'a system of ideas or way of understanding that allows us to establish knowledge. … the importance of students understanding the structure of the disciplines they are studying. … epistemes are manners of justifying, explaining, solving problems, conducting enquiries, and designing and validating various kinds of products or outcomes.' These authors examine the requisite learning structure for *bank reconciliations*, which is a single, traditionally difficult topic in Introductory Accounting, to determine whether such learning might be characterised as involving threshold concepts or perhaps is better explained through related notions of the episteme or what Lucas and Mladenovic (2006), in an earlier application of threshold theory to Introductory Accounting, have termed *threshold conceptions*.

The authors draw on an empirical study undertaken at the University of the Western Cape in which Accountancy students were questioned in the following manner:

A. If the cash book has a debit balance of 810 Rand, what balance would you expect the bank statement to have?
B. How and why, would you treat each of the following items when preparing a bank reconciliation statement?
    (i) Bank charges on the bank statement.
    (ii) Cheques made out in the cash book but not yet presented for payment to the bank.
    (iii) A cheque from a debtor which has been deposited with the bank, but which is shown as dishonoured on the bank statement.
C. The bank statement shows a debit balance of 410 Rand. There are unpresented deposits of R465 Rand. How will you treat the unpresented deposits in the bank reconciliation statement? What will the cash book balance be?

Such questions give rise to several important aspects of a bank reconciliation process. In A, the authors point out 'students are required to visualize the relationship between a business' cash records and the bank's equivalent for the business. This relationship is a *mirror* image – equal in amount, but opposite in direction – either a debit or a credit'. In B students have to deal with certain unresolved items when preparing a bank reconciliation statement, which exposes the students' understanding of the relationship between a bank statement and a cash book in greater depth, requiring them to be able to manipulate the cause and effect consequences of each situation. C also requires exercise of visualization skills in terms of how the unpresented deposits might affect the respective bank and cash book balances.

The authors conducted a series of protocol analyses of the talk-aloud interviews with the Accountancy students. For this they drew on Feuerstein et al.'s 'deficient cognitive operations' model derived from the psychosocial theory of Mediated Learning Experience (MLE). This postulates that a lack of effective mediation results in deficient cognitive operations, for example, poor visualization of relationships and lack of inferential-hypothetical reasoning. According to Feuerstein et al. (1980, p71), such cognitive deficiencies help identify *prerequisites* of thinking, and refer to 'deficiencies in those functions that underlie internalized, operational thought'. Analysis from the talk-aloud interviews revealed, amongst other phenomena, three forms of student difficulty in terms of *lack of inferential-hypothetical reasoning, narrowness of the mental field* and *poor visualisation of relationships.* These deficient cognitive operations overlap and also have an impact on the effective usage of data. In terms of the nature of the learning thresholds that these cognitive operations might constitute, the authors suggest that as they relate more to thinking skills or organizing structures than to concepts, they resemble more Lucas and Mladenovic's (2006) definition of *threshold conceptions*, rather

than concepts. Threshold conceptions are defined as 'comprising an *organising structure* or *framework* which provides the explanatory rationale for accounting techniques' (Lucas and Mladenovic, 2006, pp.153-154). The authors identify similarities in this respect Perkins' notion of the disciplinary episteme mentioned earlier. Interestingly they also point out the likely necessity of an ontological shift in overcoming these deficient cognitive operations:

> Furthermore, the cognitive operations identified in this chapter as being part of an organising structure for studying Introductory Accounting could be argued to represent an ontological shift in how the study of accounting is viewed. A focus on the thought processes underlying a topic area, such as bank reconciliations, rather than on the content itself, may be a spark to ignite a major shift in how students perceive – and ultimately study – the discipline of accounting.

In their empirical study of design education **Jane Osmond** and **Andrew Turner** (Chapter 21) note the relatively undertheorised nature of this field, observing that 'most research into design has focused on the *process* of design at the expense of the development of the designer'. They applied the threshold concept framework as a lens or 'way in' to research the specific context of Transport and Product Design Courses and to open up a research dialogue with both students and staff on the courses. Initial explorations with staff as to whether 'spatial awareness' might be a threshold concept in Transport and Product Design revealed no common definition and responses ranging from 'all round awareness' to 'design sensitivity'. Student responses, gathered through a combination of qualitative interviews and questionnaires revealed states of 'having no knowledge', 'little knowledge' or 'guessing'. Though the notion of spatial awareness was not pursued further, and seen rather as a 'design capability', the response data had nonetheless provided valuable leads to other candidate thresholds. The notion of 'visual creativity' emerged as a necessary attribute for successful design graduates but integral to this seemed to be an ontological capacity for what the authors term the 'confidence to challenge', and this seemed to operate as a learning threshold. One tutor characterises this as 'the ability to inculcate design conventions and expand upon them using information from a variety of sources and experiences'. It seems a prerequisite to enable designers to tackle what Buchanan (1992) has termed 'wicked problems', that is, those having 'incomplete, contradictory, and changing requirements; and solutions to them are often difficult to recognize as such because of complex interdependencies.' Without this shift in subjectivity, design students, the authors report, 'can remain in a liminal state, constantly "surfacing around" in search of a solution'. Interestingly this threshold seemed to present even more difficulties to those international students used to a more prescribed style of teaching and curriculum:

> I think during the very beginning I really struggled to really know what I should do in my projects - you really spend a lot of time to think about it but the result is not really that good as you expected because you keep surfacing

> around, you can't really make decisions about doing … that's one of the most negative feelings because you don't know what to do sometimes - I mean I understand you do projects it is not really satisfying teachers, you learn during the process, but still you want to know what they really want. (First year international student)

The authors draw on the design process literature to gain helpful insights into what the nature of this liminal state might entail, drawing on notions such as Tovey's (1984) 'incubation period' during which 'the two halves of the brain are out of touch or unable to agree', or the idea of 'oscillation' between problem and solution. They cite Archer's view (1979, cited in Cross 1992, p.5) that:

> The design activity is commutative, the designer's attention oscillating between the emerging requirement ideas and the developing provision ideas, as he illuminates obscurity on both sides and reduces misfit between them.

They also draw on Wallace's (1992, p.81) representation of this transformational state as 'problem bubbles' involving the solution of countless individual problems, like myriad bubbles within a larger bubble, and in which for the particular design brief to be successfully achieved 'the complete set of problem bubbles associated with the task must be solved; but many, many bubbles not directly related to the task will be entered between starting and finishing the task'.

In order to achieve the confidence to challenge, however, an intervening learning threshold was identified by the authors, namely the need to develop *a tolerance of being in a period of uncertainty*. Significantly, the authors observe, it is only after mastering toleration of this period of uncertainty that the students gain the 'confidence to challenge' and are then ready, or able, to tackle their design briefs which characteristically include the 'wicked problems' discussed earlier. This mastering of the toleration of uncertainty also clearly possesses an ontological dimension and entails a shift in subjectivity. The 'holding environment', or support structures that seemed to enable this shift are identified by the authors as including the 'inculcating skills, capabilities and coping strategies delivered via an apprentice-like immersive method of teaching underpinned by an atelier, or studio-based, environment'. The staff respondents also identified important *transition points*, key moments during the course that moved the students on through the liminal state, and which included 'first year assessments, the use of clay in the second year, exposure to the professional community of practice during the third year, coupled with the ability to work in groups and the development of empathy'.

In an interesting migration of threshold theory to the secondary sector of education **Ming Fai Pang** and **Jan Meyer** (Chapter 22) investigated dimensions of sub- and pre-liminal variation in secondary school pupils' initial apprehension, via a range of 'proxies', of the threshold concept of 'opportunity cost'. In this case the proxies were short scenarios designed to reveal variation in pupils' understanding of 'opportunity cost'. The following is an example:

> *Ben woke up at eleven and he planned to study for his exam in the afternoon. At noon, the phone rang. His girlfriend asked him to go to a movie. He decided to spend 4 hours in the afternoon with her. a. What choice did Ben make? Why did Ben have to make choice? What was the cost for Ben to go to see the movie? b. If the movie was boring, would it have increases his cost of going to the movie? Why or why not?*

Forty Secondary 3 pupils of in Hong Kong took part in the study. They were following the 'New Senior Secondary (NSS) Curriculum – Proposed Economics Subject Framework for Secondary 4-6 pupils in Hong Kong', aimed at developing pupils' interest in exploring human behaviour and social issues through a good mastery of fundamental economic themes such as 'economic decisions involving choices among alternatives' and the 'concept of cost in Economics'. The pupils were of both sexes, had not previously taken economics as a school subject and came from schools of different levels of academic attainment and in different physical locations in the city. Interviews were held in Cantonese.

The inquiry drew on Marton and Booth's (1997) 'variation theory' which posits that 'pupils' variation in the understanding of a disciplinary concept or practice, or alternative conceptions of the concept, hinges on those critical features of the concept or practice that pupils are able to *discern and focus on simultaneously'*. Hence learning is seen as a capacity to discern and focus on the critical aspects of a concept or practice. In this case the threshold concept of opportunity cost became the object of learning whose critical features would need to be discerned and understood. The study also sought to measure variation in the extent to which pupils demonstrated evidence of a subliminal or preliminal state of understanding. The former relates to the learner's awareness and understanding of an underlying game or episteme – a 'way of knowing' – which may be a crucial determinant of progression (epistemological or ontological) within a conceptual domain. The latter concerns how a threshold concept initially 'comes into view' (i.e. is initially perceived or apprehended), and the mindset with which it might be approached or withdrawn from. According to the authors, those experienced in the manners of reasoning and justifying customary to economics are likely, in reaching a rational decision, to take into account both benefits and costs. Significantly 'they focus on both the option chosen as well as the highest-valued option forgone at the same time'. This was not the case with the Secondary 3 pupils however:

> most of the pupils interviewed seem only to have some innate grasp of the allocation of preference or benefit part, and they thus focus only on the option chosen, taking for granted or ignoring the sacrifice or cost involved in choice making. Even though some pupils may have a sense of cost, what they focus on is the monetary cost involved in getting the chosen option, rather than the opportunity cost of getting the chosen option.

At one extreme, pupils failed to understand questioning related to the notions of 'choice' and 'opportunity cost' and could not demonstrate coherent ways of reasoning. At the other a few were:

> conscious of an embedded, consistent way of rationalising the phenomenon, although without the language to formalise it. They have developed an implicit way of using the concept of 'opportunity cost' to make sense of the world through the scenarios and they seemed to be 'thinking like an economist' without being aware of it.

**For these few implicitly some notion of choice or opportunity cost seemed to have** come into view, suggesting the possibility of their already having reached a preliminal stage. Still others frequently *changed their minds* whilst discussing the same scenario, indicating perhaps oscillation between sub- and pre-liminal modes of variation, or between an economic way of understanding and a lay person's way of understanding. Occasionally students demonstrated an intuitive and quite sophisticated, economic way of reasoning.

In seeking to establish a 'transformative pedagogy' the authors propose targeting the *transformation of* pupils' ways of thinking and reasoning. This requires a prior ascertaining of pupils' original, intuitive and normal 'ways of knowing' and an understanding on the part of their teachers of the variation in '*how* pupils initially perceive, apprehend, conceptualise or experience the threshold concept in the absence of any formalised knowledge of the concept itself'. This crucial knowledge will, in turn, the authors argue, 'inform an understanding of where *and why* pupils may find themselves in "stuck places" on their learning trajectory'. It also helps identify the *critical features* of pupils' initial different ways of apprehending phenomena that act as proxies for threshold concepts, and these may involve both cognitive and ontological shifts. This then can open up the possibility, in both secondary and higher education, of genuinely transformative learning designs that can aid learners in their transition from naive or intuitive understandings of economic phenomena to the more sophisticated ways of reasoning and practising normal to the community of practice.

A further interesting migration of threshold theory, in this case from education to social science, and an equally interesting ontological shift, can be found in **Dagmar Kutsar** and **Anita Kärner**'s exploration, from a threshold concepts perspective, of societal transitions in post-communist Estonia (Chapter 23). Their aim is not only to 'broaden the explanatory potential of the threshold concepts perspective of teaching and learning to examine societal transition processes in society' but also 'to develop a cognitive learning exercise from the experiences of students seeking new explanations, visions, and meanings of "the known"'. This involves applying the lens of threshold theory to an entire society at a critical point of political, social and economic transformation in the aftermath of the break-up of the Soviet state, with one political system having collapsed and being exchanged by another. In doing this society is examined as a learning and teaching environment in itself. 'The transitions are meaningful events', the authors observe, 'accompanied by uncertainties, learning the new and changing identities and structures'. During this period of social transformation, society is 'overwhelmed by a liminal space – no longer what it was and not yet what it will be. The liminal space is shared by the actors of transition, the institutions, groups

and individuals all filled with a mixture of new and old cognitions, emotions, myths and behavioural patterns'. As was pointed out at the beginning of this section, an act of learning is an act of identity formation, but, as these authors emphasise:

> Learning in rapid societal changes does not have a clear curriculum and all those involved are students. Meeting uncertainties and the 'unknown' leads to new perceptions and ('troublesome') knowledge... Examining rapid societal transitions in a particular country from the threshold concepts perspective, feels like putting the social learning process under a magnifying-glass.

The authors draw on Turner's anthropological notion of liminality, as does threshold theory itself. In their view the entire population of Estonia entered a liminal state at the time of the (peaceful) Singing Revolution. This was the historical moment, in Turnerian terms, of leaving the old and meeting the new, and when the population, the social actors, enter a liminal state of what Turner called a *no-longer-not-yet-status*. The majority of these social actors, in the authors' analysis, emerged into a post-liminal state of order at some point in the mid 1990s, with new (and stable) social and economic structures. But this did not apply to all sectors of Estonian society. Continuing the Turnerian analysis, the authors describe the formation of the *Communitas*, with its strong sense of togetherness, group experience and collective goals. This was very much occasioned by large musical gatherings or events such as The Baltic Chain peaceful protest held on the 23 August 1989:

> The *Communitas* of Estonia, Latvia and Lithuania joined together in a human chain, hand–in-hand, from Tallinn, through Riga to Vilnius as a symbol of the shared destiny of the Baltic countries and the expression of the common goals of regaining their independent statehood. Approximately 2,000,000 people joined their hands over the 600-kilometre route to show that the Baltic people had united and shared their visions of the future. During this ritual, a mantra *'Estonia/Latvia/Lithuania belongs to us'* was echoed from person to person the length of the entire human chain.

As in other studies of learning thresholds, the liminal phase was found here to be a troubling experience, not always characterised by positive emotion. The authors speak of 'emotional tensions and fears of loss of cognitive control over the situation, which results in feelings of powerlessness, dissatisfaction and alienation', attributing this to the fact that well-being acknowledges the *possibilities* but also *limitations* for action. A survey of social stress at the time revealed high levels of social distress, 'anxiety, discomfort, different kinds of fears', particularly amongst male, non-Estonian, and older members of society. As this initial period of intense transformation, and transformational learning concluded, the social actors ventured into new and often strange spaces. New social, economic and political structures emerged (popular front, heritage society, green movement, creative unions, the Congress of Estonia) and new actors joined them in these spaces, such as exiles returning from the West and newly released former Soviet dissidents. We see variation entering into the

experience of participants here, and also in terms of their role and changed status in the new social space.

> Interestingly, young people who had had a '*missing experience*', no participatory experience in the Soviet system, were popularly viewed to have more worth in facing the challenges inherent in rebuilding the nation than those, like the nomenklatura, whose experience was deemed an '*invalid experience'.*

What seems to become manifest here is that whilst certain social actors, as social 'learners', successfully negotiate this phase of transformation and emerge into a transformed postliminal state, in both senses of that term, , others – *The Others*, as the authors characterise them – remain in a liminal mode of oscillation. The non-Estonian (mainly Russian-speaking) population, we are told, 'needed more time for self re-identification and for re-positioning in the transition from being accepted as the dominant ethnic group and the speakers of the former state language (Russian) to being labelled as the ethnic minority with either weak or zero command of the state language (Estonian)'. Meanwhile the formerly powerful Soviet *nomenklatura* could be seen as remaining in a preliminal state, refusing to join the Communitas, seeking to maintain the old identities, and spreading social tension to prevent the new structures form taking hold. In keeping with the threshold theory notion of a holding environment, social myth emerged as a coping strategy for surviving the liminal state, even though the myths later 'disintegrated' in the post-liminal state.

> Social myths can be interpreted as threshold myths (Atherton et al., 2008), the functional value of which exceeds their value of being true. They are ideological beliefs with strong affective and political elements, which according to Atherton et al., (2008) serve as threshold concepts.

In the concluding chapter of this volume **Margaret Kiley** and **Gina Wisker** (Chapter 24), in a welcome application of threshold theory to postgraduate study, turn the lens of threshold theory to the field of research. In a survey of experienced supervisors in a range of different countries their concern is to identify 'conceptual challenges that candidates encountered when learning to be a researcher, how supervisors recognised that a candidate had successfully met those challenges, and how they might have assisted the candidate in that process'. The purpose of the study was to attempt to identify 'moments of research learning' or 'learning leaps' in the experience of research students, to enable supervisors to develop effective strategies to better assist them in the kinds of conceptual threshold crossing that research undertakings involve.

Their enquiry drew on earlier influential studies such as the Reflections on Learning Inventory (ROLI) (Meyer & Boulton-Lewis, 1997). This was used to inform an action research programme with a large international UK PhD programme to identify when students can be seen, or not, to develop their

approaches to, and perceptions of, the learning necessary at doctoral level. This pointed to factors such as identification of research questions, methodology and literature review as well as conceptual levels of enquiry, research design, data management, interpretation of findings and conclusions. The Students' Conceptions of Research inventory (SCoRi) was next consulted. This had aimed to identify what research students and their supervisors envisaged as the nature and purpose of research. Research into the nature of the viva and doctoral examination was then explored to gain insights into the capacity of doctoral candidates 'to present their work conceptually and to theorise and abstract their findings in ways which allowed them to have broader application'.

The convergence of these earlier dimensions of the authors' work – namely student meta-cognition, conceptual level thinking and research students' developing capacity to articulate and theorise their research learning – with the theory of threshold concepts became a catalytic point in their research. These earlier dimensions were seen as 'crucial in the development of postgraduates' doctoral learning journeys through to the crossing of conceptual thresholds and the achievement of their doctorate'. This convergence provided an initial focus to explore the conceptual crossings that students might encounter in the doctoral journey. Six candidate thresholds emerged from research data with staff and students: a) the concept of *argument* or thesis a concept which the research on doctoral examination frequently cites either because of its presence, or lack of it, in the dissertation ; b) the concept of *theory* either underpinning research or being an outcome of research; c) *framework* as a means of locating or bounding the research; d) concepts of originality and *knowledge creation*; d) *analysis* (often criticised by examiners as too 'haphazard' or 'undisciplined'); and *research paradigm*, that is 'the epistemological framing of one's approach to research'.

Building on these earlier findings the specific aims of the researchers then became the identification of:

1. How research supervisors recognise the acquisition of the threshold concepts
2. Where and how they recognise evidence they are crossing, and
3. How they 'nudge' candidates in the crossing of this threshold.

By 'nudging' the authors are referring to 'the constructive intervention of the supervisor to aid the student's conceptualised work'. This nudging takes place through 'staged interventions' during the development of the supervisory relationship at various stages of doctoral candidature. The following were recognised as particularly significant:

- The development of research questions.
- The movement from other-directed reading to self-directed and 'owned' reading of the literature leading to the development of a sound literary review.

- Working with data at different conceptual levels, analysing, interpreting and defining findings which make a contribution to understanding as well as factual knowledge.
- Developing an argument or thesis which can be sustained and supported.
- Producing the abstract and the conceptual conclusions.

These interventions were found to be key moments for helping candidates make 'learning leaps' and articulate their understanding at a conceptual level. Supervisors also identified specific elements in their supervision practices which seemed to assist their supervisees in the process of what the authors term 'conceptual threshold crossing'. These specific practices include the following:

- Encouraging engagement with the research question.
- Offering and prompting opportunities for engagement with the literature in relation to themes, issues and then in a dialogue with the candidate's own work.
- Oral prompting of conceptual work in groups, supervisory meetings, and individually.
- Encouraging conceptual and critical work with prompt feedback.
- Pointing out contradictions and tensions.
- Encouraging careful data analysis, developing themes, engaging with theories.
- Encouraging early writing and much editing-sharing and reflection.
- Using the language of 'doctorateness' e.g. conceptual framework, and the ideas, the research and theories of learning e.g. meta-cognition.
- Offering opportunities to articulate ideas and achievements in mock *vivas* and other oral presentations.

The authors contend that evidence of a candidate's behaviour changes is often a proxy indication that the student has crossed a particular conceptual threshold and that this indicates a change in subjectivity, a 'shift, a change, in the learner's appreciation and understanding of her/himself as well as what has been learned'. Though these ontological shifts often incur challenge and a degree of troublesomeness and challenge, they generally were found to occasion new insights and new levels in the ongoing work.

> Students are perceived to be changing their ways of working, their contribution to meaning, and also changing in terms of behaviour, particularly their ways of going about their learning. Identity is then an important factor noted by supervisors in terms of the changing ways students engage with, conduct and articulate their research.

## CONCLUSION

We hope that the chapters that follow in this book convey something of the vibrancy and engagement that characterised the conference in Ontario where they were first presented and discussed. It is encouraging to see the widespread adoption of the thresholds framework across many disciplines, institutions and countries, and its migration into new sectors and fields. Our thanks are due to the many writers included in this volume, and to the generosity of their colleagues and students in contributing their time, thoughts and feelings in discussion and dialogue about learning thresholds and troublesome knowledge in a common endeavour to gain better insights into student learning and conceptual difficulty. As we go to press with this volume plans are already well under way for a third international conference on thresholds to be held in Sydney in July 2010, jointly hosted by the Universities of Sydney and New South Wales. We look forward with great anticipation to further engagement around this continually intriguing theme, to renewing discussions with old friends and embarking on future explorations with new ones.

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Glasgow, Durham and Perth WA
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